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COMPOSITION OF SEWAGE SLUDGE AS INFLUENCED BY TYPE OF DISPOSAL SYSTEM

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Modern developments in sewage plant construction and operation make particularly desirable a new look at the products that are potentially available for use as fertilizers and as soil conditioners in agriculture.

It is well known that biochemical reactions take place at a rapid rate in sewage sludge. The microorganisms involved are active from the time material enters a sewer until dry sludge is prepared. Inoculating materials abound along the course traveled by the liquids and solids. The end products of sewage treatment have often been shown to vary widely in chemical composition and in agricultural usefulness, depending upon the processing operation. Activated, strongly aerated sludge on the one hand has a place as a fertilizer or fertilizer material. Digested sludges, fermented in the absence of air, regardless of possible previous activation, are of relatively low value as carriers of available plant nutrients. They are sometimes used as constituents of mixed fertilizers, however, and for direct application to soil.

It is the purpose here to examine a few sewage products taken at two or more stages of processing where different systems of treatment are used. In this way one can expect to determine something of the character and rate of changes taking place, as well as something of the influence of intake materials on the composition of end products. This is a study of the chemistry of sewage decomposition in some of the modern disposal plants.

Improved quality of effluent with attendant cleaner streams is very often a major objective in sewage plant design. From this standpoint sewage disposal plants of greater and greater efficiency have been developed during recent years. In some plants the incoming sewage follows a rather direct route through the several chambers of the system. In other cities, however, better quality effluent is possible when materials follow a more devious route.

During recent years several developments have tended to change the chemical composition of incoming sewage. Some of these changes have perhaps made disposal more difficult. Among the factors involved are: (1) Widespread use of synthetic detergents and scouring powders of high soluble phosphate content; (2) Operation of home garbage grinders and (3) Contributions from various industrial plants.

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Home garbage grinders reduce bones to sufficiently small particle-size so that these highly phosphatic materials are processed with sewage; vegetable tops, potato peelings and other waste materials may contribute large quantities of carbohydrates that must be fermented. Industrial wastes often contain metals as fragments or as compounds of these materials in solution or suspension.

Chemical changes taking place in materials treated in different types of of disposal plants are known to vary greatly. The two major types of disposal systems differ greatly in character of chemical action promoted and in chemical composition of final products.

It seems pertinent here to compare certain chemical data for sludges prepared by the two major systems including various modifications within such systems. Published data provide some of the information (1)[2] while data recently taken by this Department more nearly completes the chemical picture. Data for activated sludges are given in table 1, and for digested products in table 2.

Table 1 shows large increases in phosphoric oxide contents of modern activated sludges over products prepared in the manner some 20 years ago. The data for digested sludges given in table 2 show some increase in P_2O_5 content but the increases are not as large proportionately as are shown for activated material. A period of about 20 years has brought about very little change in the average nitrogen contents of sludges from activation or digestion systems.

In order further to characterize modern sewage sludges from a chemical standpoint, summarized values for minor element contents of the two types of sludges are given in table 3. The elements copper, zinc, boron, manganese and molybdenum each show wide variations in the different sludges. These differences probably reflect the influence of industrial products entering the system as well as varied materials contributed from households.

Quality of nitrogen in sludge, that is its rate of availability to plants when placed in soil, is an item of great interest to prospective users of sludge as fertilizer. Determinations of rates of nitrification in sludge are conventionally made after specified periods of incubation with soil. Such data have been obtained for modern sludges representative of different disposal systems. Average values are shown graphically in Figure I. The data confirm the well-known fact that nitrogen of activated non-digested sludges is much more readily nitrified than is the nitrogen of digested material (2, 3). These data show also that most of the nitrification accomplished during a growing season takes place within a month after incorporation with soil. The graphs for the two classes of materials are approximately the same in character but representative of very different degrees of nitrification.

Tables 1 and 2 show that the total nitrogen contents of activated sludges tend to be about two and one-half times the amounts in digested products. Figure I shows the rate of nitrification of the activated material to be about 2½ times that in digested sludge. If the value of sludge were to be based exclusively on content of quickly nitrifiable nitrogen, the value of activated sludges should be about six times that of digested products on a weight basis. Any relative evaluation must take into account character of soil to which the fertilizer is to be added, however, and kind of crop to be grown.

2/ Italic numbers in parentheses refer to Literature Cited p. 10

Table 1

Nitrogen and phosphoric oxide contents of activated sewage sludges prepared about 20 years ago, compared with material recently processed; summarized data

Time of Preparation of Sludge and Level of Constituent	Nitrogen (N)	Phosphoric Oxide (P_2O_5)
	Percent	Percent
Sludge of 20 years ago:		
Average Value	6.0	3.2
High Value	6.4	3.8
Low Value	4.4	2.0
Sludge of 1951 to 1955:		
Average Value	5.6	5.7
High Value	6.0	7.4
Low Value	4.8	4.0

Table 2

Nitrogen and phosphoric oxide contents of digested sewage sludges prepared about 20 years ago and recently; summarized data

Time of Preparation of Sludge and Level of Constituent	Nitrogen (N)	Phosphoric Oxide (P_2O_5)
	Percent	Percent
Sludge of 20 years ago:		
Average level	2.2	2.1
High level	3.0	3.8
Low level	1.3	0.8
Sludge of 1952:		
Average level	2.4	2.7
High level	3.1	5.0
Low level	1.8	0.9

Table 3

Minor element contents of two groups of recently processed sewage sludges; summarized data

Kind of sludge and level of element	Copper (Cu)	Zinc (Zn)	Boron (B)	Manganese (Mn)	Molybdenum (Mo)
	ppm	ppm	ppm	ppm	ppm
Activated sludges					
Average value	916	2500	33	134	16
High value	1500	3650	74	190	45
low value	385	950	6	65	6
Digested sludges					
Average value	643	2459	9	262	6
High value	1980	3700	15	790	12
Low value	315	1350	4	30	2

Chemical Action in Disposal Systems

Various sewage samples have been obtained through the cooperation of responsible city officials. Very brief descriptions of each of the plants whose products were studied are given here:

The Washington, D. C., plant discharges its effluent into the Potomac River below Washington City. Primary treatment of sewage is the dominant feature. Heat-treatment of sludge has recently been provided. The sludge is now in condition to be offered for sale, but thus far there has been no financial return. Two samples of freshly settled solids are included in order that some information regarding seasonal variations in incoming sewage solids may be provided.

The Baltimore plant provides primary and secondary treatment; activated material is subsequently digested. The heat-treated sludge is sold at a nominal price to be used as a constituent of mixed fertilizers. A 30-acre field of trickling filters improves the effluent for commercial use of the water.

Each home in the small city of Jasper, Indiana, has a garbage grinder. The influence of home garbage on the composition of incoming sewage can be studied from these products (6).

The Richmond, Indiana, plant processes both sewage and garbage using a combination activation-and-digestion system. The city garbage is collected and brought to the plant where it is sorted, ground and mixed with the sewage. Farmers utilize most of the end product.

The Southwest Chicago Plant is one of the large institutions utilizing activation. The heat-treated sludge is sold for incorporation in mixed fertilizers.

A sample of a final product from the Milwaukee Plant is included here. Incoming solids not passing a screen of about 2 millimeter mesh are discarded to an incinerator. Removal of this class of solids elminates much material of low plant nutrient content. The primary objective is to deliver the best quality water possible to Lake Michigan. Excellent quality heat-treated sludge finds ready markets at a good price.

In each case incoming solids are of light gray color, fibrous and presenting the general appearance of containing much shredded paper. The contrasts in appearance between incoming and fully treated materials are shown in Figure II.

Chemical data from each of the disposal plants previously mentioned are given in Table 4. The data show several features worthy of attention. Activation causes an increase in the nitrogen content of solids. These relatively high values are presumably built up in part by bacterial action transforming water-soluble nitrogen into the bodies of organisms whose nitrogen contents are reported to range from 7 to 11 percent (4).

Digestion tends toward higher ash contents with loss of some nitrogen. Digestion tends also to improve the sanitary condition of sludge. Large amounts of combustible gas are given off during the digestion process. This gas can easily be used to heat-treat the sludge, making it safe for immediate use in garden soil. Activated sludges that particularly need heat-treatment for sanitary protection do not not supply the necessary fuel during processing.

The phosphoric oxide contents of sludges vary in accordance with the intake of this constituent modified by loss in total weight during the digestion process. A very small amount of phosphorus may be expected in the effluent.

Carbon-nitrogen ratio values that are so widely used by soil scientists serve as an approximate measure of the extent of decomposition of organic matter taking place between the different stages at which materials of a disposal system are sampled. The high carbon-nitrogen values given in table 4 for incoming sewage reflect the presence of large amounts of carbohydrates known to be included in the intake material. The rapid drop in values is indicative of decomposition. Time factors are not definite, but activation probably changes carbon relations more rapidly than does the digestion process. Activated materials reach a lower carbon-nitrogen ratio than is accomplished by digestion. In this way the carbon-nitrogen ratio is related to fertilizer value of the sludge.

Organic carbon was determined by the Walkley-Black wet combustion method (5). Calculations are based on the assumption that 77 percent of the carbon present is recovered. This value, developed for soils, may be subject to greater error when applied to sludge materials. This means that ratios are probably a little higher than would be the case if dry combustion data were used, particularly for materials entering a processing plant.

pH values of sludge are influenced to some extent by materials such as ferric chloride that are frequently added. Varied features of processing and variations in the composition of incoming materials may also influence pH. The pH value of sludge may in some cases influence the use that may be made of these city products. Certain users of organics must avoid the application of neutral or alkaline materials to their soils.

Table 4 - CHEMICAL COMPOSITION OF SEWAGE SLUDGES IN DIFFERENT STAGES OF PROCESSING IN SEVERAL CITY DISPOSAL PLANTS: TOTAL CONSTITUENTS, DRY BASIS

Location of plant and State of processing	Nitrogen (N)	Carbon (C)	Carbon: Nitrogen ratio	Phosphoric oxide (P_2O_5)	Ash	pH
	percent	percent		percent	percent	
Washington, D. C.						
Incoming solids (spring)	2.42	43.46	18.0	1.14	32.35	5.3
Incoming solids (summer)	2.39	43.69	18.3	1.09	37.59	5.6
Digested sludge	2.06	28.59	13.9	1.44	52.83	5.8
Baltimore, Md.						
Incoming solids	2.23	47.09	21.1	1.29	24.16	5.7
Activated sludge	2.36	30.37	12.9	11.01	29.70	5.5
Humus tank sludge	5.34	37.90	7.1	3.96	32.30	5.9
Heat-dried product	3.05	36.53	12.0	2.97	39.73	5.0
Jasper, Ind.						
Incoming solids	2.90	42.31	14.6	1.62	32.29	5.7
Activated sludge	3.51	23.01	6.6	2.81	52.43	6.8
Final dried product	5.89	22.95	3.9	3.49	36.96	5.8
Richmond, Ind.						
Incoming solids	3.80	28.21	7.4	5.19	40.94	7.6
Activated sludge	3.02	44.04	14.6	3.64	31.37	6.2
Digested sludge	2.24	26.36	11.8	4.34	50.09	6.9
Chicago, Ill. Southwest plant						
Raw sludge	2.70	46.62	17.3	2.71	28.24	4.5
Activated sludge	4.98	28.62	5.7	5.58	34.82	6.2
Sludge fertilizer	5.56	29.41	5.3	6.56	37.42	6.0
Milwaukee, Wisconsin						
Final heat-treated sludge	5.96	20.88	3.5	3.96	27.73	4.8

Suggestions

This brief presentation on the biochemistry of modern sewage sludges leaves many questions unanswered. Certain topics appeal to the author as suitable for consideration by college students on senior or graduate levels. A few suggested subjects are listed below:

1. To what extent is the phosphorus of modern sewage sludges available to plants?
2. Do the specific feeding powers of various plants differ with respect to their utilization of phosphorus in sludges?
3. What chemical characteristics of sludges influence rate of nitrification most effectively?
4. Biology of the trickling filter.
5. How is the high nitrogen content of activated sludges developed?

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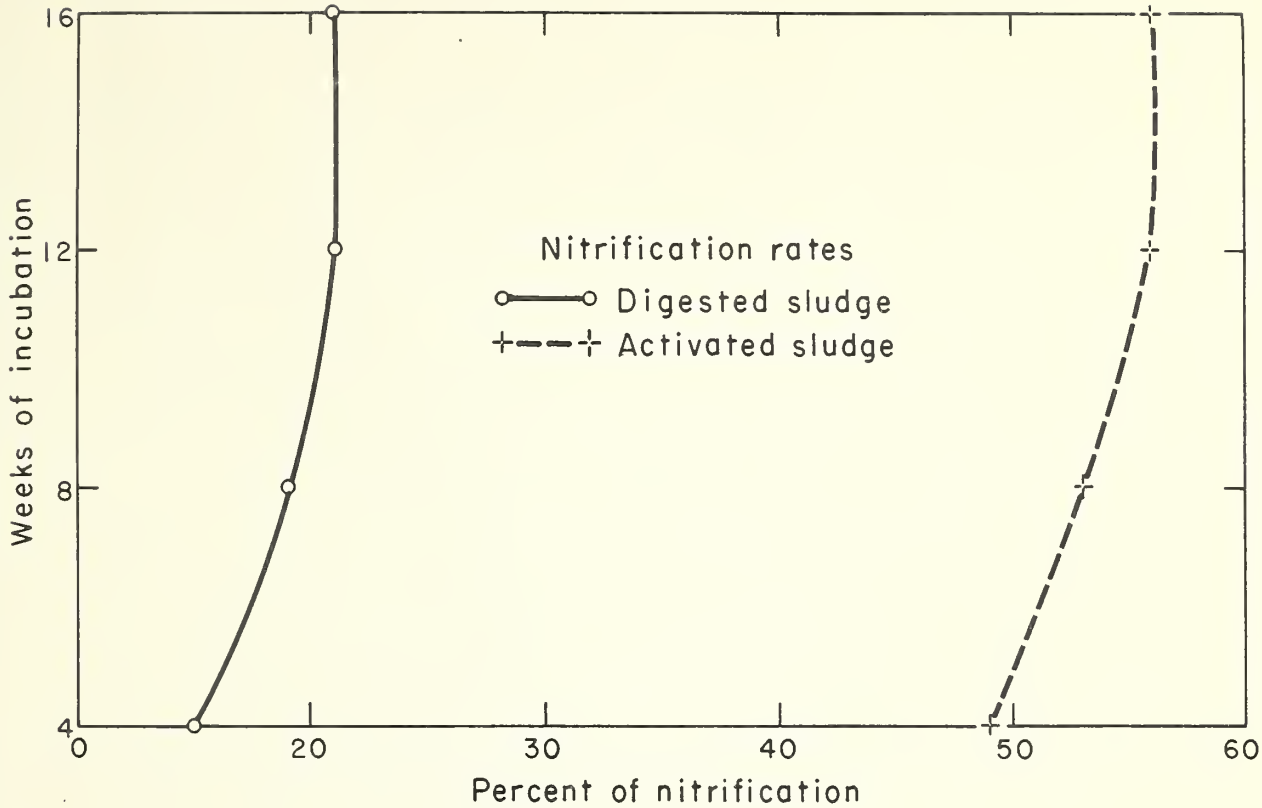

Figure 1. Rates of nitrification of sewage sludges differently prepared (average values).